To evaluate the LC pretilt angles of the alignment layer polyamide using the Taguchi method

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ABSTRACT

Alignment of liquid crystal induced by rubbing is not only interesting in physical chemistry but also important as a fundamental technology of mass production of liquid crystal devices. A detailed investigation on the influences of various rubbing parameters and temperature on the polyamide film has been carried out to study the temporal behavior of the pretilt angle. We also use the Taguchi Method of the Quality Engineering to prove the evaluated value and experimental value of the pretilt angle. The possibility of using the method as in-line control parameters of the alignment process in an actual LCD production facility is considered.

Keywords: Taguchi method ‧ pretilt angle ‧ rubbing density

1.PREFACE

It is well known that uniform alignment of liquid crystals over a large area is a prerequisite for the optimal performance of various types of liquid crystal display devices[1]. Therefore a polymer, like polyamide, has been used as a liquid crystal alignment layer[2]. In order to obtain an excellent alignment, the polymer film is rubbed with a roller covered with a cloth, and consequently the outer layer of the rubbed film is oriented[3]. One of the important parameters of liquid crystal alignment is the pre-tilt angle that influences the viewing angle characteristics and electrooptics properties of the LCDs[4]. The pre-tilt angle is a critical parameter to control the optical properties of liquid crystal display, like creation of reverse-tilt domain、steepness of voltage-transmission curve and response time. However, the pre-tilt angle will be affect by the curing temperature[5]、rubbing density and pile impression in alignment process [6,7]. Since materials have its own characteristic, different pre-tilt angle may be got even using the same process condition. This experiment focuses on the material of SE-7492 only. It is challenging to find out the condition of process for expected pre-tilt angle, it maybe have to try many times. Taguchi method[8] is widely used in design of experiment to get the sufficient data with limited experiments and to compare sensitivity of these parameters. In this paper, we present results of deviation between measured data and evaluated data by the Taguchi method.

2.EXPERIMENT

The polyamide (PA), SE-7492, is obtained from Nissan. The PA films were performed by curing the samples at 280°C for 30 minutes after prebake at 70、90 or 110°C for 5 minutes. Thickness of PA films were controlled in the range of 95~105nm. The rubbing conditions were as follows: rubbing density=100、200,pile impression=0.2、0.4 and 0.6mm.The cells were filled with the Merck's liquid crystal in a vacuum chamber under 200torr at room temperature, and the cells were sealed with the UV glue. Thickness of cells were controlled in the range of 40~50μm. In these experiments the filled antiparallel cells were annealed at 95°C for 90min. The pretilt angles at two different spots in a uniform area of each anti-parallel cell were measured at room temperature by the crystal rotation method[9], and the average value is reported. In these experiments, variable parameters were prebake temperature (70、90 and 110°C)、rubbing density (100、200) and pile impression (0.2、0.4 and 0.6mm). The definition of the rubbing density was taken from reference[10]. If we shall try all condition, we have to do eighteen times. Since we use the Taguchi method, we can calculate the freedom is 5 from the variable amount of parameters. It is suitable for use L_6 design of experiment[8]. Each experiment tests twice and experiment orders were as follows:

	Prebake	Pile impression	Rubbing density
1	70°C	0.2	100
2	70°C	0.4	200
3	90°C	0.6	100
4	90°C	0.2	200
5	110°C	0.4	100
6	110°C	0.6	200

In *Display Technologies III*, I-Wei Wu, Heiju Uchiike, Editors,
Proceedings of SPIE Vol. 4079 (2000) • 0277-786X/00/$15.00

3.RESULTS

We assume prebake temperature 70°C、90°C and 110°C as A1、A2 and A3 respectively；pile impression 0.2、0.4 and 0.6mm as B1、B2 and B3 respectively；rubbing density 100 and 200 as C1 and C2 respectively. These results were listed as follow：

	Prebake	Pile impression	Rubbing density	Result 1	Result 2	Average
1	A1	B1	C1	9.96	9.85	9.91
2	A1	B2	C2	7.62	7.22	7.42
3	A2	B3	C1	7.45	7.09	7.27
4	A2	B1	C2	9.83	9.74	9.79
5	A3	B2	C1	8.74	8.49	8.62
6	A3	B3	C2	5.86	5.84	5.50

Average T=(9.91+7.42+7.27+9.79+8.62+5.5)/6=8.14

$\overline{A1}$=(9.91+7.42)/2=8.67

$\overline{B1}$=(9.91+9.79)/2=9.85

$\overline{C1}$=(9.91+7.27+8.62)/3=8.6

And so on $\overline{A2}$=8.53，$\overline{B2}$=8.02 $\overline{C2}$=7.69

$\overline{A3}$=7.23，$\overline{B3}$=6.56

Evaluated equation by Taguchi method:

$$\mu=T+(\overline{A}-T)+(\overline{B}-T)+(\overline{C}-T)$$

Ex. experiment No 1.

Prebake：70（°C），Pile impression：0.2（mm）

Rubbing density：200

The evaluated value：

μ=8.14+(8.67-8.14)+(9.85-8.14)+(7.69-8.14) =9.93

Table 1.Evaluated data by the Taguchi method and measured data from experiments

No	A	B	C	Evaluated data	Measured data
1	1	1	2	9.93	9.82
2	1	2	2	8.09	7.59
3	1	3	2	6.63	6.26
4	1	1	1	10.82	10.18
5	1	2	1	9.00	8.78
6	1	3	1	7.54	7.48
7	2	1	2	9.79	9.93
8	2	2	2	7.96	7.94
9	2	3	2	6.50	6.59
10	2	1	1	10.70	10.24
11	2	2	1	8.87	9.00
12	2	3	1	7.41	7.51
13	3	1	2	8.49	9.42
14	3	2	2	6.66	7.31
15	3	3	2	5.20	5.93
16	3	1	1	8.94	9.70
17	3	2	1	7.57	8.64
18	3	3	1	6.11	7.25

**The gray areas are indicated those are conditions by the Taguchi method.

4.DISCUSSION

The deviations between measured data and evaluated data by the Taguchi method are showed in Fig 1,there are very good correspondence. At prebake 90°C, the deviations are lower than our expectation. However, there are large deviations at 110°C (the maximum is 1.14°), these results are acceptable for us.

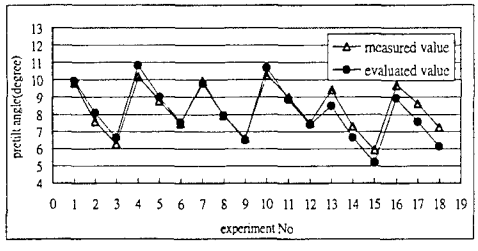


Figure 1. The deviations between measured data and evaluated data by The Taguchi method.

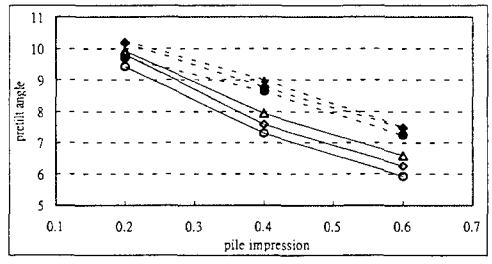
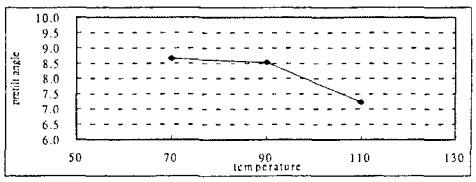


Figure 2.Effects of pretilt angle (measured data) with variable of each parameter.



(◇ : prebake 70°C , rubbing density 200)
(△ : prebake 90°C , rubbing density 200)
(○ : prebake 110°C , rubbing density 200)
(◆ : prebake 70°C , rubbing density 100)
(▲ : prebake 90°C , rubbing density 100)
(● : prebake 110°C , rubbing density 100)

Figure 3.Temperature dependence of pretilt angle by The Taguchi method.

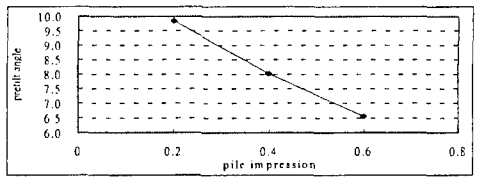


Figure 4. Pile impression dependence of pretilt angle by The Taguchi method.

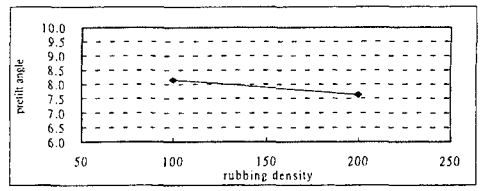


Figure 5. Rubbing density dependence of pretilt angle by The Taguchi method

Fig 2 shows the effects of pretilt angle with each parameter. It is known that pretilt angle becomes lower according to increase of the pile impression (in conditions of moderately large pile impression) [11] and rubbing density. However, temperature dependence of pretilt angle has seen different tendency. At 90°C, pretilt angle is higher than others in the same rubbing condition. Figure 4~6 show dependence of pretilt angles, that are evaluated by the Taguchi method, on variable parameters. Figure 4~5 show their tendency are the same as Figure 2. Nevertheless, in Figure 3, the pretilt angle does not vary much with the rubbing process for low-temperature processing. It is seen correspondence to Figure 2 about temperature dependence of pretilt angle. In Figure 5,the slope of line is very small than others. This probably indicates that pretilt angles are more affected sensitively by pile impression and prebake temperature, even if the variable amounts are not identical. Using the Taguchi method, we can get very good results to compare with measured data. So this method will be helpful in process control and experiment design.

REFERENCE

1. J. Cognard, Mol. Cryst. Liq. Cryst., Suppl.,1,p.1,1982
2. B. O. Myrvold, Liq. Cryst.,3,p.1255,1988
3. M. Nishikawa et.al., Proc. Japan Display, 92,p.819,1992
4. A. Lien, R. A. John, M. Angelopoulous et.al., Appl. Phys. Lett,67,p.3108,1995
5. I. Hirosawa, N. Sasaki et.al., IDW,p.133,1997
6. D. S. Seo, S. Kobayashi, M. Nishikawa, and Y.Yabe, Liq. Cryst.,19,p.289,1995
7. B. O. Myrold, Y. Iwakabe, S.Oh-Hara, and K. Kondo, Jpn. J. Appl. phys.,32,p.5052,1993
8. G. I. Taguchi, "Introduction to design of experiment, 3rd ",1993
9. T. J. Scheffer and J. Nehring, J. Appl. Phys.,48,p.1783,1997
10. D. S. Seo, H. Matsuda, T.Oh-Ide and S. Kobayashi., Mol. Cryst. Liq. Cryst, 224,p.13,1993
11. K. W. Lee, A. Lien, H. Fukuro., Euro Display ,p.319,1996